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Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report results from a contract tasking University of Oslo as follows: Under this proposal we give technical support for year around operation of two scintillation receivers. The two receiver systems are located at Longyearbyen (78.92^{0}N, 11.95^{0}E, 76.07 CGMLat) and Ny-Ålesund (78.20^{0}N, 15.82^{0}E, 75.12 CGMLat), both stations on Svalbard. These receivers provide stereo observations of irregularities in the vicinity of the auroral oval and inside the polar cap. Both receivers are operated remotely and data are transferred to AFRL via our computer network. We also support AFRL's operation of an allsky imager at Ny-Ålesund.

15. SUBJECT TERMS

EOARD, Space Weather, Radio Propagation, Solar Physics

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Contract No: FA8655-06-1-3060-P0002

PHASE 3 – FINAL REPORT

on

POLAR CAP AND POLAR CAP BOUNDARY PHENOMENA

by

Professor Jøran Moen, PI

25 June, 2009

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1. Campaigns

1.1 Optical observations Ny-Ålesund
21 Nov – 6 Dec 2008
22 Dec – 31 Dec 2008
15 Jan – 31 Jan 2009
16 Feb – 28 Feb 2009

1.2 Optical observations Longyearbyen
3 Nov - 10 Nov 2008
20 Nov – 8 Dec 2008
17 Dec – 26 Dec 2008
2 Jan - 4 Jan 2009
13 Jan - 31 Jan 2009
11 Feb – 28 Feb 2009

1.3 ICI-2 Rocket Campaign
During this campaign we conducted a coordinated optical and EISCAT radar campaign to cover the ICI-2 sounding rocket launch window from 28 Nov – 7 Dec 2008, 07:00-11:00 UT (10-14 MLT). Detailed diagnostics of launch conditions was provided by the CUTLASS HF radar, EISCAT Svalbard Radar (ESR), and the all-sky imagers located at Ny-Ålesund and Longyearbyen. We used the ACE-satellite in the solar wind to provide 1 hour forecasts of the cusp auroral location/ activity level. The optical instruments were operated continuously day and night.

2. ICI-2 sounding rocket : Investigation of Cusp Irregularities.

The main objectives of the ICI-2 mission was to resolve density gradients/structures down to meter scale and to test the gradient drift instability mode for generation of HF backscatter irregularities.

Instrumentation:
- Fixed Bias Langmuir probe – ISAS/JAXA
- Low energy electron spectrometer (10eV-10keV) - ISAS/JAXA
- Solid state particle spectrometers for electrons and ions – University of Bergen. (>20 keV)
- New Concept multi-Langmuir Probe – UiO.
- AC and DC Electric field + wave experiment, UiO.
- SRADS: Sounding Rocket Attitude Detection System, UiO

ICI-2 was launched 10:35 UT on 5 December, it reached an altitude of 330 km, and had a ~10 minutes flight time, and had 3 encounters of HF backscatter. It traversed regions of Kinetic Alfvèn Wave and inverted V signatures. The spatial resolution of the electron spectrometer data was ~10 m and we measured absolute electron densities at 5.7 kHz sampling rate during the flight. We resolved decametre HF backscatter targets as intended. The first ICI-2 data workshop will take place in Oslo from 9-10 September 2009.

2. Science Production

2.1 Publised in JGR:

J. Geophys. Res., 113, A09220, doi:10.1029/2008JA013061, 2008.

On the relationship between thin Birkeland current arcs and reversed flow channels in the winter cusp/cleft ionosphere

Moen J., Y. Rinne, H. C. Carlson, K. Oksavik, R. Fujii, H. Opgenoorth

Abstract: In this paper we study reversed flow events (RFEs) that seem regulated by Birkeland current arcs in the winter cusp ionosphere above Svalbard. An RFE is a longitudinally elongated, 100–200 km wide channel, in which the flow direction is opposite to the background convection, persisting for 10–20 min. The RFE onset occurs with the brightening of a discrete arc near the open-closed boundary. The auroral arc is situated exactly at a sharp clockwise flow reversal, consistent with a converging electric field and an upward field-aligned current. One category of RFEs propagates into the polar cap in tandem with poleward moving auroral forms, while another category of RFEs moves with the cusp/cleft boundary. The RFE phenomenon is addressed to a region void of electron precipitation, and in lack of direct sunlight the E-region conductivity will be very low. We propose two possible explanations: (1) the RFE channel may be a region where two MI current loops, forced by independent voltage generators, couple through a poorly conducting ionosphere and (2) the reversed flow channel may be the ionospheric footprint of an inverted V-type coupling region. Electron beams of <1 keV will not give rise to significant conductivity gradients, and the form of a discontinuity in the magnetospheric electric field will be conserved when mapped down to the ionosphere, although reduced in amplitude. These two explanations may be related in the sense that the boundary discontinuity in the magnetospheric electric field in (1) may be the driver for the inverted V in (2).

2.2 Published in Annales Geophysicae

www.ann-geophys.net/26/2427/2008/
Ann. Geophys., 26, 2427–2433, 2008

On the diurnal variability in F2-region plasma density above the EISCAT Svalbard radar

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Abstract. Two long runs of EISCAT Svalbard Radar (ESR), in February 2001 and October 2002, have been analysed with respect to variability in the F2 region peak density and altitude. The diurnal variation in the F2 peak density exhibits one maximum around 12:00 MLT and another around 23:00 MLT, consistent with solar wind controlled transport of EUV ionized plasma across the polar cap from day to night. High density plasma patch material is drawn in through the cusp inflow region independent of IMF BY . There is no apparent IMF BY asymmetry on the intake of high density plasma, but the trajectory of its motion is strongly BY dependent. Comparison with the international reference ionosphere model (IRI2001) clearly demonstrates that the model does not take account of the cross-polar transport of F2region plasma, and hence has limited applicability in polar cap regions.

Keywords. Ionosphere (Plasma convection; Polar ionosphere) – Magnetospheric physics (Polar cap phenomena)

2.3 Published in Annales Geophysicae

www.ann-geophys.net/26/2871/2008/
Ann. Geophys., 26, 2871–2885, 2008

On a new process for cusp irregularity production

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[2]Utah State University, CASS, Logan, UT, USA [3]Arctic Geophysics, The University Centre in Svalbard, Longyearbyen, Norway

Abstract. Two plasma instability mechanisms were thought until 2007 to dominate the formation of plasma irregularities in the F region high latitude and polar ionosphere; the gradient-drift driven instability, and the velocity-shear driven instability. The former mechanism was accepted as accounting for plasma structuring in polar cap patches, the latter for plasma structuring in polar cap sun aligned arcs. Recent work has established the need to replace this view of the past two decades with a new patch plasma structuring process (not a new mechanism), whereby shear-driven instabilities first rapidly structure the entering plasma, after which gradient drift instabilities build on these large "seed" irregularities. Correct modeling of cusp and early polar cap patch structuring will not be accomplished without allowing for this compound process. This compound process explains several previously unexplained characteristics of cusp and early polar cap patch irregularities. Here we introduce additional data, coincident in time and space, to extend that work to smaller irregularity scale sizes and relate it to the structured cusp current system.

Keywords. Ionosphere (Ionosphere-magnetosphere interactions; Polar ionosphere) – Magnetospheric physics (Auroral phenomena)

2.4 JGR in press

Searching for ULF Signatures of the Cusp: Observations from Search Coil Magnetometers and Auroral Imagers in Svalbard

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Marc R. Lessard and Hyomin Kim, University of New Hampshire, Durham, NH
Joran Moen, Department of Physics, University of Oslo, Oslo, Norway
Dag A. Lorentzen, The University Centre in Svalbard, Longyearbyen, Norway

Abstract. Spacecraft traveling through the cusp at altitudes ranging from near the magnetopause to just above the ionosphere have consistently found the cusp to be filled with intense but irregular power in both electric and magnetic fields in the upper ULF frequency range (up to at least 4 Hz). Some ground-based studies using induction magnetometers have observed Pc 1-2 (electromagnetic ion cyclotron) waves in this same frequency range in the general vicinity of the footpoint of the cusp, but it has not been possible with magnetometers alone to either confirm or deny a cusp source for any of these waves. We report here on the first simultaneous, collocated observations of a set of induction magnetometers installed at three near-cusp sites on Svalbard (Ny-Ålesund, Longyearbyen, and Hornsund), and an all-sky auroral imager (with λ = 630.0 and 557.7 nm) located at Longyearbyen. Data during northern winter 2006-2007, when the cusp footpoint was in darkness, showed occasional narrowband Pc 1-2 wave events and frequent broadband noise when energetic particle precipitation occurred overhead, but on nearly all days broadband ULF power was not observed above the noise level near noon when only soft cusp precipitation or poleward-moving auroral forms (PMAFs) occurred overhead. However, on January 15, 2007 several bursts of band-limited Pc 1-2 wave power were observed during an interval of southward IMF Bz, in association with PMAFs (or “regions of intense precipitation”) whose intensity peaked near the poleward edge of the region of cusp precipitation. These wave bursts became progressively more linearly polarized east-west at more southerly stations, consistent with subionospheric propagation equatorward from a point at or northward of NyÅlesund. This latter event is consistent with waves originating in the plasma mantle just poleward of the cusp, as observed in a recent satellite-ground study by *Engebretson et al.* [2005]. These observations confirm that even intense cusp precipitation is not effective in generating ion cyclotron waves that penetrate to the ground, if it is embedded within the central regions of the cusp, whereas regions of enhanced precipitation at the poleward edge of the cusp are associated with observed waves.

2.5 In peer review for Annales Geophysicae

Modulation of nightside polar patches by substorm activity

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Abstract

Results are presented from a multi-instrument study showing the influence of geomagnetic substorm activity on the spatial distribution of the high-latitude ionospheric plasma. Incoherent scatter radar and radio tomography measurements were used to directly observe the remnants of polar patches in the nightside ionosphere and to investigate their characteristics. The patches occurred under conditions of IMF Bz negative and IMF By negative. They were attributed to dayside photoionisation transported by the high-latitude convection pattern across the polar cap and into the nighttime European sector. The patches on the nightside were separated by some 5° latitude during substorm expansion, but this was reduced to some 2° when the activity had subsided. The different patch separations resulted from the expansion and contraction of the high-latitude plasma convection pattern on the nightside in response to the substorm activity. The patches of larger separation occurred in the antisunward cross-polar flow as it entered the nightside sector. Those of smaller separation were also in antisunward flow, but close to the equatorward edge of the convection pattern, in the slower, diverging flow at the Harang discontinuity. A patch repetition time of some 10 to 30 min was estimated depending on the phase of the substorm.

2.6 In peer review for JGR

Shock Aurora: Ground-based Imager Observations

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Abstract

This paper studies dayside shock-aurora forms and their variations observed by the ground based all-sky imager (ASI) in Svalbard on November 30, 1997. The interplanetary shock arrived at the Earth when Svalbard was at ~1120 MLT. The ASI detected an auroral intensification by a factor of 2 or more in both green and red line emissions within 5 min after the shock arrival. The intensified green emissions were mainly diffuse aurora on closed field lines. They were latitudinally below and adjacent to the red aurora that was mainly in arcs and beams along the magnetic east-west direction. The diffuse aurora expanded equatorward and eastward while its intensity exceeded the red arcs, which were at ~5 kR. We confirmed that the eastward propagating diffuse aurora was actually moved anti-sunward, which suggests that the anti sunward propagating shock-aurora seen in space is mainly diffuse aurora. The intense diffuse aurora could be caused by wave instabilities led by the temperature anisotropy and/or caused by the enlarged loss cone. After the shock arrival, the low latitude boundary of the cusp moved equatorward at a speed of ~18 km min^{-1}. As a result, the cusp meridional width was doubled from ~0.8° to 1.6° in latitude in 10 min. This implies that a low-latitude reconnection occurred during the compression. But in this event, the reconnection rate was not higher than that in low solar wind pressure condition, which is not consistent with some theory.

3. Disclosure of inventions

I certify that there were no subject inventions to declare during the performance of this grant.

4. Key Personnel at UiO

Prof. Jøran Moen
Ms. Yvonne Rinne (Ph.D. student)
Ms. Ellen Osmundsen (Ph.D. student)
Dr. Bjoern Lybekk (Senior Engineer)
Mr. Espen Trondsen (Senior Engineer)